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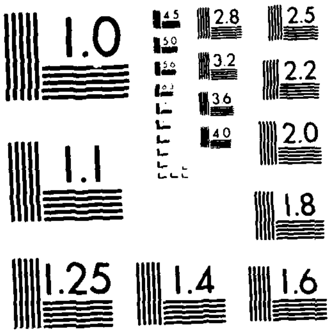
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SATELLITES FOR MOBILE COMMUNICATIONS -

CIVILIAN AND DEFENSE APPLICATIONS

by

Diane M. B. Duplissis

B.S., State University of New York,

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ABSTRACT

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Satellites have, in the past, primarily been used to provide fixed communications. Advances in both satellite and terminal technologies have made larger, more powerful satellites and smaller, portable earth terminals possible. This analysis examines the feasibility of using satellites to provide mobile communications. Operational concepts of a land mobile satellite system and three such proposed systems are discussed. The benefits of a land mobile satellite system as well as civilian applications of such a system are reviewed. Policy issues facing the Federal Communications Commission (FCC) and its decision to, or not to, allocate radio spectrum to a land mobile satellite system is also examined.

National defense, vitial to our national security, is dependent upon the ability to communicate. The Department of Defense increasingly relies upon satellites to provide communication between widely dispersed mobile units. The review of present and future defense mobile satellite systems illustrates the special defense communications issues that must be considered in the development and employment of defense mobile satellite communications systems.

This thesis for the Master of Science degree by

Diane M. B. Duplissis

has been approved for the

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S. W. Maley

Dale N. Hatfield

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Satellites for Mobile Communications - Civilian and Defense Applications
Thesis directed by Professor S. W. Maley

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CONTENTS

FIGURES

CHAPTER I

INTRODUCTION

Satellite technology has improved significantly since the Soviet Union launched Sputnik in 1957. The "race for space" was on. Advances in satellite components and launch vehicle capabilities have improved exponentially over the last two and one-half decades. Communication via satellites is no longer a novelty or the passing fancy of the scientific community. Satellite technology has advanced so quickly that the use of satellites for communication has become an indispensible part of our everyday lives.

Satellites provide a wide variety of communications services ranging from private, individual and commercial applications to various uses by the Department of Defense. These services include transmission of telephone, television, and data communications. Broadcast services, interactive education, medical data, emergency services, electronic mail, traffic information, weather and land surveillance, navigational data for ships and planes and military

integrated with similar information from the terrestrial cellular systems, the originating call would query the system to find out if the mobile unit is switched on; and if so, where is the mobile unit located (either terrestrial cell or satellite spot beam). If the mobile unit is located within a terrestrial cell, the call will be routed through the terrestrial system. If the mobile unit is not located in a terrestrial cell, then the call is routed terrestrially to the feeder-link base station that supports the spot beam the mobile unit is presentlv in. Figure 2-1 illustrates a generic mobile satellite system. However, the frequencies in the figure are only proposed; frequencies have not yet been allocated to the mobile system.

System Description

The land mobile satellite system consists of the space segment and the ground segment equipment. Although the satellite launch vehicle plays an important role in LMSS, the discussion that follows will only consider the actual permanent segments of the LMSS.

unit is unsuccessful in acquiring a terrestrial channel, or if the call is not completed before the mobile unit drives out of range of the terrestrial system, then an open mobile satellite channel would be requested in the spot beam in which the mobile unit is located. Using the feeder link that services the cell where the mobile unit is, the satellite then establishes a connection between the mobile unit and the satellite base station. The satellite base station is connected to the terrestrial public switched telephone network (PSTN). The channel established between the mobile unit and the office is a duplex channel; the return path from the base station is through the feeder uplink to the satellite and the channel is downlinked to the mobile unit at UHF frequencies.[2]

The second scenario considers a mobile unit being called by a fixed telephone, perhaps the home office. In order to receive the call, the mobile user must have the terminal switched on. His mobile telephone number could be stored in an on-line computer database. Automatically, the satellite could continuously update the database as to which spot beam the mobile unit is in. If this database is

advocate for implementing a mobile satellite system, has sponsored various studies to evaluate the benefits, costs, technical aspects and market demand for a terrestrially compatible LMSS. These studies have indicated that such a system is not only technically and economically feasible, but highly desirable. However, because these studies were commissioned by NASA, a possibility exists that the results could be slanted towards the pro-mobile satellite system and not totally objective.

Operational Concepts

Two typical scenarios illustrate how a land mobile satellite service (LMSS) compatible with a terrestrial cellular system would operate. The first scenario considers a mobile telephone operator driving from New York to Washington, D.C. He wants to call his home office in Baltimore and places the call. His mobile transmitter first searches for a terrestrial mobile base station within its range, and if it is successful, the call is connected through the terrestrial system. The call will continue in the terrestrial system as long as the mobile terminal is within range of any terrestrial base station. However, if the

CHAPTER II

SYSTEM DESCRIPTION

Introduction

The operation of a mobile communications service via satellite, or Land Mobile Satellite Service (LMSS), as it is commonly called, is conceptually similar to the operation of the urban cellular radio telephone systems presently being installed in many cities today. The main difference is the height of the base station tower. In a satellite system, this height is 22,300 miles--the height of a satellite in geosynchronous orbit.[1] The LMSS consists of two segments; they are the space and ground segments. The space segment consists of the launch vehicle and satellite in geosynchronous orbit, and the ground segment includes the mobile or portable terminal, and a base station.

The type mobile satellite system most likely to be built is one that will be compatible with and capable of augmenting the present terrestrial cellular radio telephone systems. NASA, a strong

Notes - Chapter I

[1]Dr. Kamilo Feher, Digital Communications (Englewood Cliffs, N.J.: Prentice-Hall), 1983), p. xvii.

[2]James Martin, Communications Satellite Systems (Englewood Cliffs, N.J.: Prentice-Hall, 1978), p. 2.

[3]Ibid.

[4]F. Naderi, "An Advanced Generation Land Mobile Satellite System and Its Critical Technologies," IEEE National Telesystems Conference, November 7-10, 1982 , p. B1.1.1.

[5]Martin, p. 9.

[6]Ibid., p. 10.

[7]Gerard O'Neill, "The Geostar Satellite System," Satellite Communications, March, 1984, p. 64.

[8]National Aeronautics and Space Administration, to Federal Communications Commission, Petition for Rulemaking - Mobile Satellite Service, November 24, 1982, p. 11.

[9]Ibid., p. 12.

developing and fielding mobile satellite communications for the armed forces.

Chapter VI provides a brief summary of the previous chapters, and comments on the issues being faced in both the civilian and defense sectors of the nation.

Included is a proposed integrated satellite and terrestrial telephone system, the use of satellites to provide interactive data and surveillance service, agricultural and forestry uses, emergency medical assistance, help during and after natural disasters or emergencies, and mobile maritime applications.

Chapter IV discusses telecommunications policy issues presently before the Federal Communications Commission (FCC). The FCC has a petition before it requesting allocation of radio spectrum for a land mobile satellite service.

Chapter V discusses defense applications of a mobile satellite system. There are important issues facing the Department of Defense and its use of satellites for mobile communications. While the majority of the "mobile" communications systems fielded by the DOD are more transportable than actually mobile, the use of satellites gives the armed forces a more flexible, mobile, responsive and redundant capability during peacetime, crises, and war, than ever before. Chapter V outlines the DOD requirements for mobile communications and discusses some of the considerations that must be made in

satellites can provide extremely valuable services to all aspects of society. As technology improves and the costs decrease from the implementation of large-scale component production, the development of mobile systems will accelerate at an ever-increasing rate.

In order to facilitate an understanding of how and why satellites can be useful in providing mobile communications, both for the civilian and defense segment of the nation, Chapter II discusses and illutrates the concept, design and operation of a generic mobile satellite communication system. Also discussed is a petition for rulemaking submitted by NASA to the Federal Communications Commission, and applications for licensing to provide a mobile satellite communication service submitted by two commercial enterprises. Because the concepts are basically the same for both civilian and defense mobile communications satellites, only the proposed civilian system will be discussed. Differences in the applications between civilian and defense satellites will be discussed in Chapters III and V, respectively.

Chapter III contains a discussion of the various applications, both tested and proposed, for civilian land mobile satellite communications system

civilian and military arenas. Civilian applications of mobile communication via satellite include providing communications services to the rural market where providing terrestrial service is costly and impractical. Mobile satellite communications are useful in industrial, agricultural and prospecting activities which are normally carried on in rural areas of the country. Mobile communications via satellite can also provide valuable services during natural disasters and emergencies. Mobile communications using satellites is also a logical way to augment and complement the urban cellular radio telephone systems now being installed throughout the urban centers of the country. This application would provide a truly ubiquitous nation-wide communications system.

On the defense side, applications of mobile communications in wartime include command and control of all military resources such as the ground mobile forces, strategic nuclear forces, and naval forces. In many instances, military communications assets are used in peacetime to augment civilian equipment during emergencies and natural disasters.

Although the use of satellites for mobile communications is a rather recent development,

even carried in a pocket or purse.[7] A transportable or mobile earth station enables communication with another party, via satellite, regardless of the users' locations.

Historically, mobile telecommunications services in the U.S. have only been available through terrestrial facilities. This has limited the range of mobile communications to basically line-of-sight (LOS) distances. The availability of mobile communications is also limited to those areas where the population is sufficiently large and concentrated enough to economically justify the investment in the transmitter sites, base station equipment and towers required for mobile communications.[8]

However, if satellites are used to augment terrestrial mobile communications, the above line-of-sight and population restrictions will no longer be applicable. Mobile communications between a satellite and a mobile terminal that is similar in cost and technology to terrestrial mobile terminals is both economically and technologically feasible.[9]

Because mobile communications using a satellite are both technically possible and economically feasible, broad applications for such a moble communications system are recognized in both the

system costs will mainly be dominated by the cost of the ground facilities.[5]

Although the space segment costs of a satellite communication system have dropped dramatically, the cost of an earth station has dropped even more spectacularly than that of a satellite. The first COMSAT earth stations cost over $10 million. But now earth station costs have decreased so much that a powerful transmit-receive earth station can be bought for about one one-hundredth of that original cost. A receive-only earth terminal can be purchased for a fraction of that cost. Therefore, the investment cost per channel per earth station is dropping rapidly.[6]

While communicating over satellite links via fixed earth stations provides a significant improvement in communications capabilities, advances in technology have made mobile communication via satellites not only feasible, but highly desirable today. The trend to larger and more powerful satellites allows the use of smaller, less complex and less expensive earth terminals. These smaller earth terminals are lightweight "transceivers" that can be installed in a car, boat, plane and eventually

complexity has made using satellites for communications expensive. Only large corporations could provide satellite communications services because they had the vast capital needed to invest in satellite systems and expensive ground stations.

Satellite ownership in the past has been limited to large corporations such as INTELSAT, or COMSAT. These corporations provide communications between powerful, fixed earth stations. In order for the satellite communications to be cost effective, individual channels are routed to an earth station, multiplexed together and transmitted to the satellite. The satellite retransmits the signal to another ground station which provides the interconnectively to terrestrial communications systems, either through cable or microwave. Communication lines or circuits via satellite are then leased to individual customers or corporations.

The components of a satellite communications system include the space segment and earth station facilities. The space segment of satellite communications includes the satellite itself and all aspects of launching that satellite into space. With improvements in technology, the space segment costs have been dropping to such low levels that future overall

Because the ground stations use large antennas and powerful transmitters, the signal is able to reach relatively small and unsophisticated satellites.[4] In the past, ground stations had to be large because the size of the satellites has been limited up to now by the size, weight, and payload capability of the launch vehicle. Because satellites have been limited in size and weight, their output power has also been limited. Satellite antenna sizes have also been small because of these weight and size restrictions.

Because the strength of the transmitted signal decreases as the square of the distance from the earth station to the satellite, either the satellite or the earth station must be large enough to receive the signal. Small satellites with low output power require large, complex, and powerful earth stations in order to offset the satellite limitations. Large earth stations require high powered transmitters in order for the signal to reach a satellite that is more than 22,000 miles away. The earth station receiver must be extremely sensitive in order to receive the faint satellite signal that traveled the great distance back to earth. This

strategic and tactical data are additional services provided by the satellites.[1]

Satellite systems, unlike terrestrial communications systems, have the flexibility to interconnect any pair of users that are separated by great distances, or obstacles in terrain. A satellite system consisting of three satellites can virtually cover the entire globe (with the exception of the extreme polar regions). And the costs of satellite communications are basically insensitive to the distances between the terminals while terrestrial communication systems costs are dependent on the distance between terminals.[2]

According to James Martin, a noted author in the field of telecommunications,

> a communications satellite, in essence, is a radio relay in the sky. Signals are sent to it from antennas on earth; it amplifies the signals and sends them back. The power of satellites lies in the fact that they can handle a large amount of traffic and send it over most of the earth.[3]

Satellites used for fixed communications have become well established in the past two decades. Most communication satellite systems route signals from widely dispersed users to a few powerful ground stations. These signals are trunked, multiplexed together and then transmitted to the satellite.

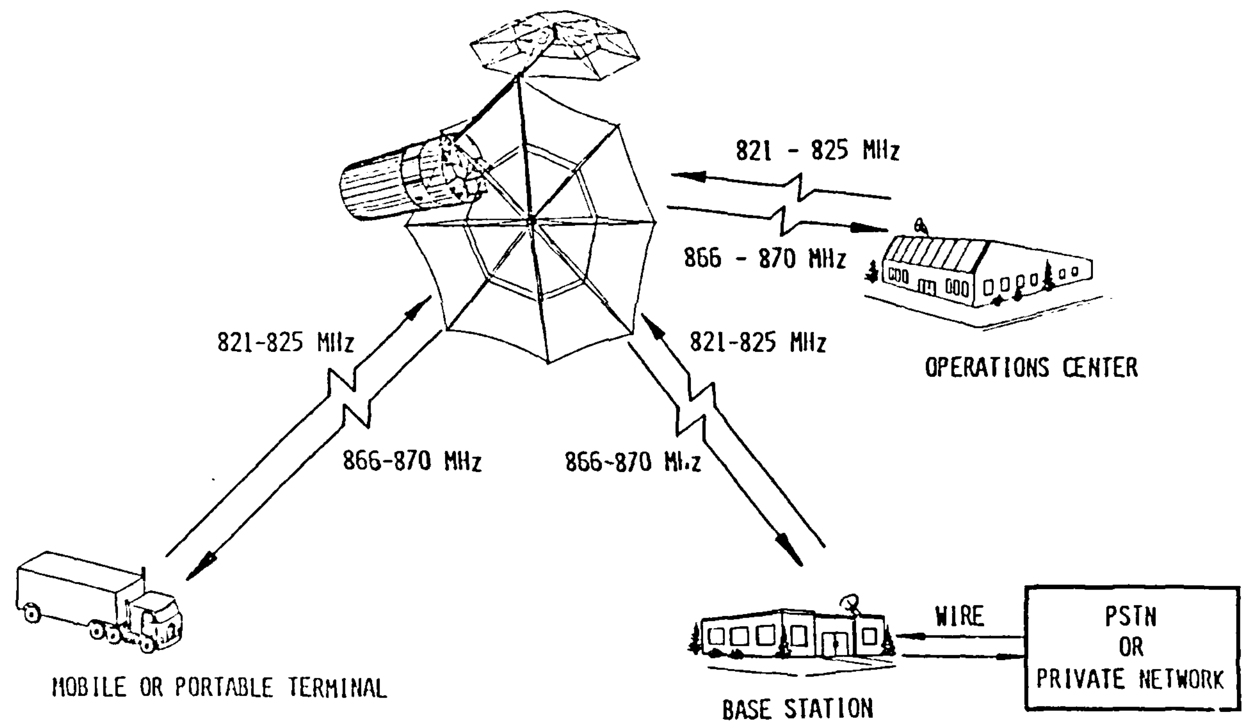


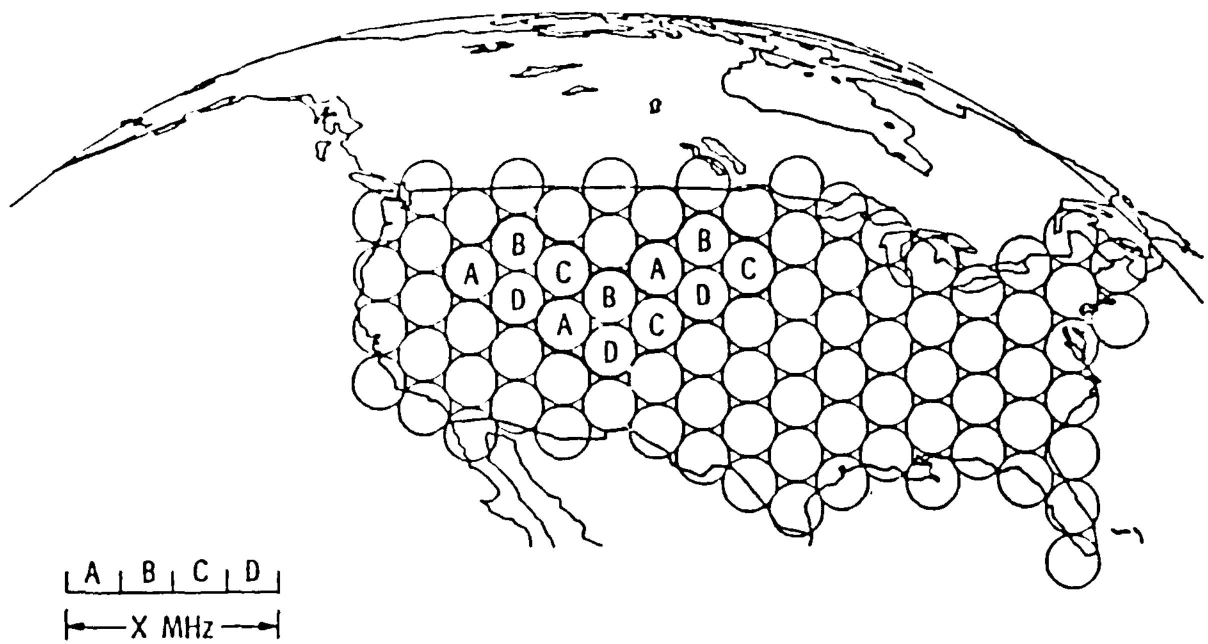
Figure 2-1. Land Mobile Satellite System. (Adopted from Application of Skylink Corporation for a Developmental Land Mobile Satellite Service, September 1983.)

Space Segment

The focal point for the LMSS is a large and powerful geostationary satellite with multiple beams, capable of communicating with hundreds of thousands of mobile users.[4] To achieve this capability, the satellite is envisioned to use a 20-50 meter antenna with 10-25 beams. A satellite with a large antenna is necessary for two reasons. The first is to compensate for the low gain of the small, nearly omnidirectional antenna of the mobile terminal. The second reason a large antenna is used is to provide multiple spot beams that will allow frequency reuse of the scarce radio spectrum.[5] An example provided by NASA uses an offset, direct fed, parabolic reflector configuration satellite. If a 50-foot antenna is used, 18 beams, each with a 1.6 degree beamwidth, would provide a four-frequency pattern with a minimum frequency reuse factor of four. Figure 2-2 illustrates the concept of frequency reuse and spectrum conservation.

For power, the satellite would use two large deployable solar arrays that unfold once the satellite reaches its orbital position. The actual size and type of solar panels will be designed to provide power to meet or exceed the designed lifetime of the satellite.[6]

CONCEPT OF FREQUENCY REUSE



X = TOTAL ALLOCATED SPECTRUM

A, B, C, D = REUSABLE SUBBANDS

Figure 2-2. Concept of Frequency Reuse. (Source: NASA, June 1984)

Mobile terminal. A variety of mobile terminals are envisioned to meet the requirements of the users whether they be on land, in the air, or at sea. Proponents of the LMSS envision using a mobile terminal that is the same or similar as the ground equipment presently being used with the terrestrial system. This would enable satellite users to dial into the terrestrial network and allow terrestrial network users to access the satellite.[7] Proposed frequencies are 821-825 MHz for the uplink and 866-870 for the down link. The mobile transmitter power for a satellite system is approximately the same as it is for terrestrial cellular systems. Because the satellite is at a higher angle of elevation than a terrestrial base station transmitter, the antenna of a mobile terminal can be designed to discriminate against ground reflections and thereby reduce the probability of interference from buildings. Although the satellite's elevation angle improves reception, trees, buildings, overpasses and terrain features that come between the vehicle and the satellite will interfere with communication. However, most of these interruptions should be temporary in nature and should not severely affect the understanding of the messages.[8]

Gateways or base stations. Gateways or base stations (they fulfill the same functions) in the LMSS will be located in each beam in order to provide the interface with the direct dial network, terrestrial access points, svstem switching and access control facilities of the public switched telephone network (PSTN).[9] The gateways will control channels within the beam and provide interbeam service by routing traffic to other gateways.

Control station or operations center. The control station performs two major functions. As the primary telemetry tracking and control facility, it is responsible for monitoring and controlling the satellite. This includes ensuring the satellite properly maintains its orbital position and attitude. It is also the central monitor and control facility for the various communication services that are provided.[10] The control station maintains overall system control and would be continuously manned.

Summary

A satellite communications system can provide mobile communications in rural areas where terrestrial cellular systems limited by distance and terrain, would be impractical. However, there are problems inherent in satellite communications systems.

Multipath reflections, shadowing effects of trees and other obstacles, and the movement of the mobile terminal as it travels cause signal fading. This fading is on the order of 10 dB and the proponents of a mobile satellite system feel that this "would not be a serious detriment . . ."[12] to a mobile satellite system.

The concept of a mobile satellite communications system is a rather simple one. Only three major components are necessary: the satellite, the mobile terminal, and a gateway to interconnect the mobile unit with the terrestrial land lines system. Each of these is within our present technological capabilities.

Land Mobile Satellite Service (LMSS) Proposals

The United States has, up to now, not yet allocated any radio spectrum for a land Mobile Satellite System. The National Aeronautic and Space Administration (NASA) has conducted experiments and sponsored studies for more than seven years concerning land mobile satellites. NASA has concluded from these studies that a LMSS is technically and economically feasible, and highly desirable if the

nation is to have a ubiquitous mobile communications system. These conclusions prompted NASA to petition the Federal Communications Commission (FCC) to begin a proceeding to look into the establishment of a commercial Land Mobile Satellite Service.[13] Subsequent to NASA's petition, two commercial corporations submitted to the FCC, proposals for building a commercial mobile satellite system and applications for licensing this system. These proposals are discussed below.

NASA's Proposal

On November 24, 1982, the National Aeronautic and Space Administration filed a Petition for Rulemaking with the Federal Communications Commission (FCC). This petition for rulemarking urged the FCC:

> to institute a rulemaking proceeding looking toward the amendment of its rules to establish a Mobile Satellite Service with specific allocations at 821-825 MHz and 866-870 MHz, in order to augment terrestrial mobile telephone and private mobile communications systems.[14]

Figure 2-3 illustrates the concept of an integrated terrestrial Land Mobile Satellite System (LMSS) while Figure 2-4 depicts possible operational systems.

The proposal requests the FCC begin rulemaking to consider the following:

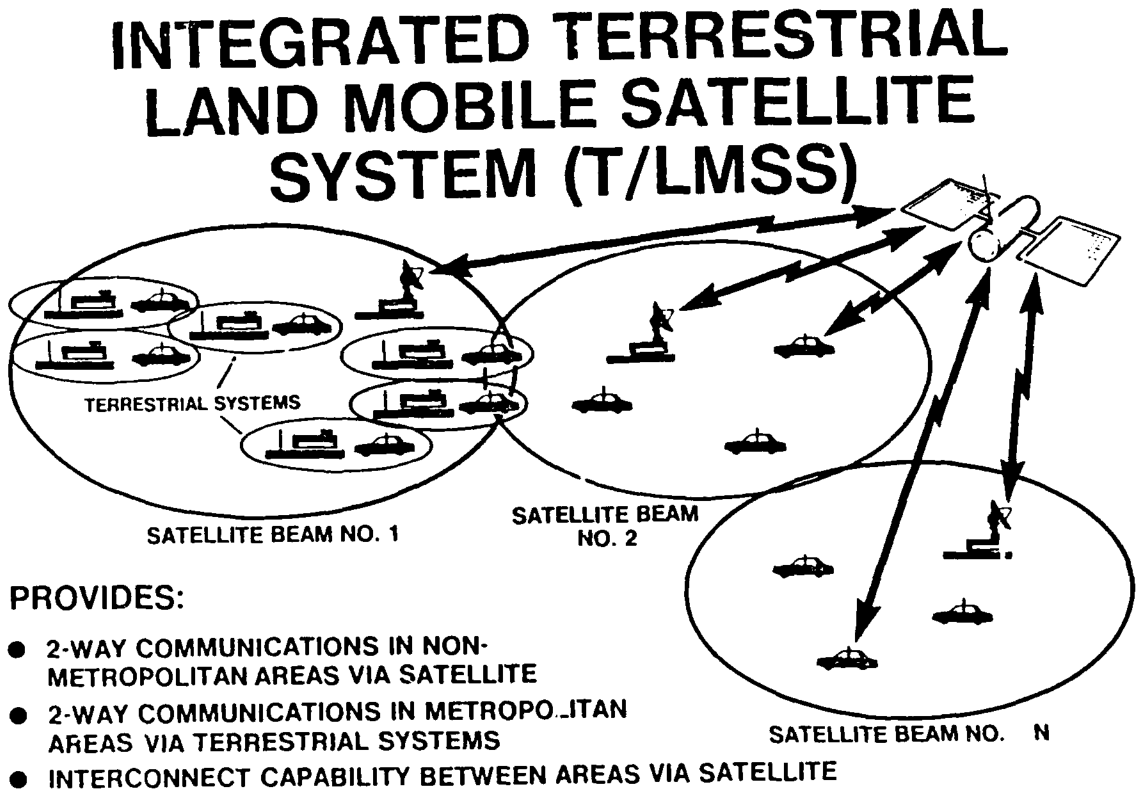


Figure 2-3. Integrated Terrestrial/Land Mobile Satellite System.
(Source: NASA, June 1984)

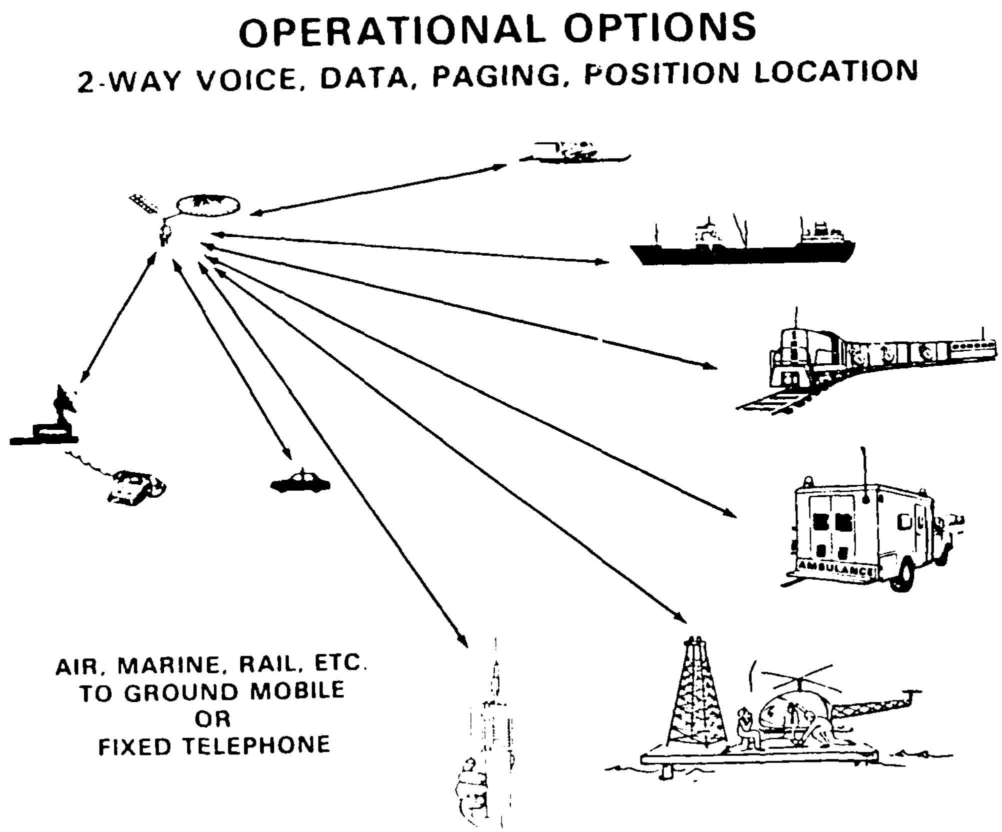


Figure 2-4. Operational Options. (Source: NASA, June 1984)

1. Allocation of spectrum (821-825 MHz and 866-870 MHz) currently in reserve to the Mobile Satellite Service on a primary basis.[15]

2. Continuation of the reservation of spectrum (845-851 MHz and 890-896 MHz) until 1990, so sufficient spectrum is available for the "commercial phase" of a mobile satellite service if it is deemed feasible after evaluating the results of experimental use of the bands allocated in 1 above.[16] Figure 2-5 illustrates the present spectrum allocation and NASA's proposed spectrum allocation.

3. Allocation of spectrum (35-80 MHz in each direction at either the S-Band or Ku-Band) for "feeder-link" purposes.[17] Feeder-links will provide access to and from the satellite to the public switched telephone network (PSTN) through fixed satellite earth stations.

NASA feels if its proposal is approved and spectrum allocated, it: 1) will be possible to "demonstrate the technical and economic feasibility of a mobile satellite service,"[18] 2) will not delay or "adversely affect the implementation of either cellular or non-cellular terrestrial mobile services,"[19] and 3) will hold spectrum in reserve

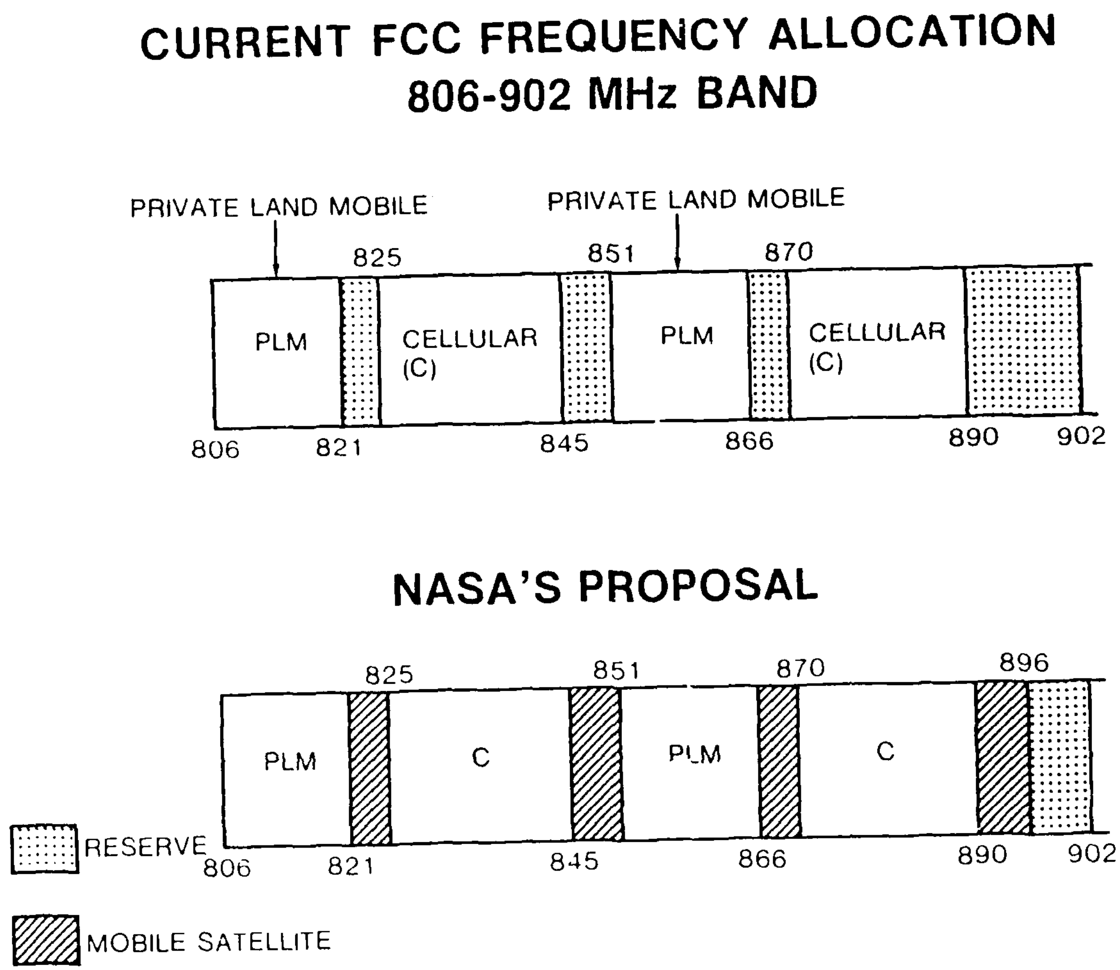


Figure 2-5. Frequency Allocation. (Source: NASA, June 1984)

while the needs for additional spectrum are appraised based on data collected during an experimental phase.[20]

NASA discusses several reasons to justify its proposal to implement a LMSS in the above frequencies. These include the following: First, a LMSS in the 821-825 and 866-870 MHz band can augment both terrestrial cellular and private mobile radio.[21] Second, NASA contends there is a "substantial rural market for . . . satellite-based mobile services . . . which will not be economically serviceable by terrestrial systems."[22] Third, NASA feels if the satellite system is designed to augment the terrestrial system, and the mobile terminal is "capable of working with both terrestrial and satellite base stations,"[23] mass production of equipment could lower costs, and ubiquitous mobile coverage would be available.[24]

Commercial Proposals

Two commercial firms submitted proposals for a land mobile satellite system subsequent to NASA's petition for rulemaking. These proposals are briefly discussed below. The first corporation proposes to use two major technological advances it has

developed to make commercial mobile satellite service available for the first time. One "will reduce the spectrum required for digital signaling by a factor of five; the other will improve overall satellite power conversion efficiency by 300 percent."[25]

This firm proposes to use the 800 MHz reserve bands; 821-825 MHz (uplink) and 866-870 MHz (downlink). The proposal also specifies that the "same UHF bands used for the satellite to remote links are reused for the satellite to base 'feeder' links."[26] Using this technique provides higher spectrum conservation and a much lower base station terminal hardware cost than systems using S-Band or Ku-Band feeder links.[27] In essence, "no feeder link or backhaul channels will be necessary."[28] However, the firm envisions requiring approximately 1 MHz at the edge of either C or KU-Band for their telemetry, tracking and control (TT and C) function. The exact frequency required will be determined and requested at a later date.[29]

This firm's system will use a satellite with two 16-foot diameter high-gain antennas and high efficiency amplifiers.[30] A Network Operations Center (NOC) would control the network.[31] The demand

assignment multiple access (DAMA) system would allocate one channel to any terminal in the network on demand.[32]

The corporation proposes to provide 800 single channel per carrier (SCPC) channels that would cover North America in its initial operational phase. The system is envisioned to eventually provide up to 30,000 channels.

The complex circuitry, power and size will be placed on board the satellite so the ground terminals used can be small and relatively inexpensive.[33] The firm's mobile terminal is expected to weigh less than five pounds and be technically similar and comparable in price to the cellular radio telephone on the market today. Dual-compatible phones (operable in both the satellite and cellular mode) will be available.

This corporation furnishes arguments that are similar to NASA's for application approval. However, the firm emphasizes the importance of international cooperation between Canada and the U.S., the importance of maintaining U.S. technological leadership, and balance of trade issues as additional items that must be considered in the overall licensing process.

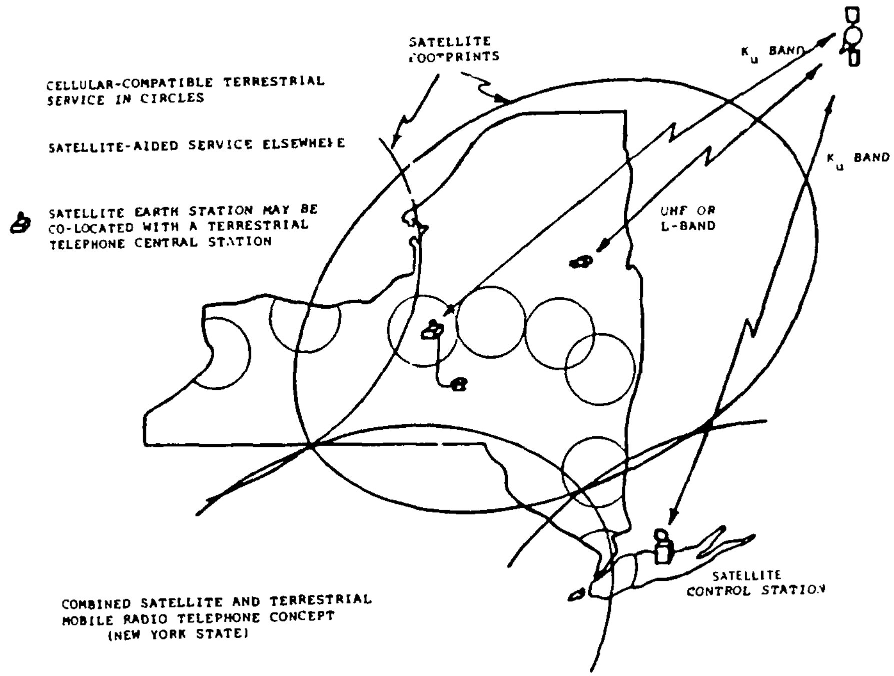


Figure 3-2. Integrated Terrestrial/Satellite System. (Adapted from Roy E. Anderson, "Satellite Augmentation of Cellular Type Mobile Radio Telephone Systems," ACTA Astronautica, 9, no. 8 (1982), 513.

urban subscriber of terrestrial cellular mobile service to use the satellite system when out of range of the terrestrial cellular system. Figure 3-2 illustrates how New York State would be served by an integrated terrestrial/land mobile satellite system. Each small circle represents an urban area that could conceivably be served by a terrestrial cellular radio telephone system. If a subscriber within a small circle wants to place a call, the mobile terminal in his vehicle would place the call automatically on a terrestrial channel. The large oval in the figure represents the "footprint," or earth coverage, of a spot beam, 0.5 degrees wide, from a geostationary satellite at 110 degrees west longitude. The overlapping oval lines represent the adjacent beam footprints.[16]

When a user is in a rural area outside the small circles, the mobile terminal will automatically access the system via the satellite. The signals from the vehicle to the satellite are on UHF or L-band. They are then relayed to a small earth station or gateway on some higher frequency, perhaps in the Ku-band. The gateway automatically assigns specific channel pairs within the beam subset

International cooperation with Canada in a joint mobile satellite communications venture could prove mutually advantageous to both Canada and the U.S. If a LMSS were jointly developed and compatible for use in Canada and the U.S., both countries would enjoy significant cost savings through the sharing of certain facilities, improved reliability and interoperability in times of emergency.[15]

Civilian Applications

There is a wide assortment of services that a land mobile satellite service (LMSS) can provide, ranging from mobile radio telephone service to wideband data transmission. This is possible because satellite transponders are "transparent" to the type of signals, bandwidth and modulation that is transmitted and received. This section examines some of the prominent uses of mobile satellite communications that have been proposed.

Integrated Terrestrial/Land Mobile Satellite Service

The operational concepts and scenarios described in Chapter II provide an understanding of how an integrated terrestrial/land mobile satellite system would work. The system would enable an

of the nation. Industries such as commercial trucking, oil and gas exploration, lumber, electric power utilities, etc., primarily operate in widely dispersed rural and remote areas. A mobile satellite communications service could improve their overall operational efficiency, increase productivity, reduce costs in industries which are vital to the national interest, and pass the savings on to the consumer.[11]

International Benefits

Many of the international benefits discussed here follow directly from the technical and economic benefits examined in the above sections. The nation's technological leadership is important to our economic growth and national defense.[12] We must rely on innovation and quality for our superiority in space technology. Economically,

> the sale of our communications satellite equipment and launch services has been a significant source of trade revenue for over a decade.[13]

This has had a positive effect on our foreign balance of trade problems. If we continue to be the technical leaders in space technology, we will encourage developing nations to purchase their communications satellite systems and launch services from us.[14]

reuse and multiple access techniques, design of large multibeam spacecraft antenna, and high-gain, low cost, small mobile antennas.[6] U.S. efforts to develop the mobile satellite service would promote technical leadership in telecommunications technology.[7]

Economic Benefits

There are several economic benefits arising from the technical benefits of implementing a mobile satellite communications service. In addition to the space segment of the system, the ground equipment market, both for mobile terminals and gateway stations, is large. A mobile satellite communications system would "create a multibillion dollar hardware market,"[8] and would "provide the stimulus and vehicle for further U.S. innovation and leadership in space."[9]

Competition, the principle our economic system is based on, would increase in the telecommunications industry. This competition would quickly lower the cost and improve the quality of mobile terminals, thus benefiting both the individual and the nation.[10]

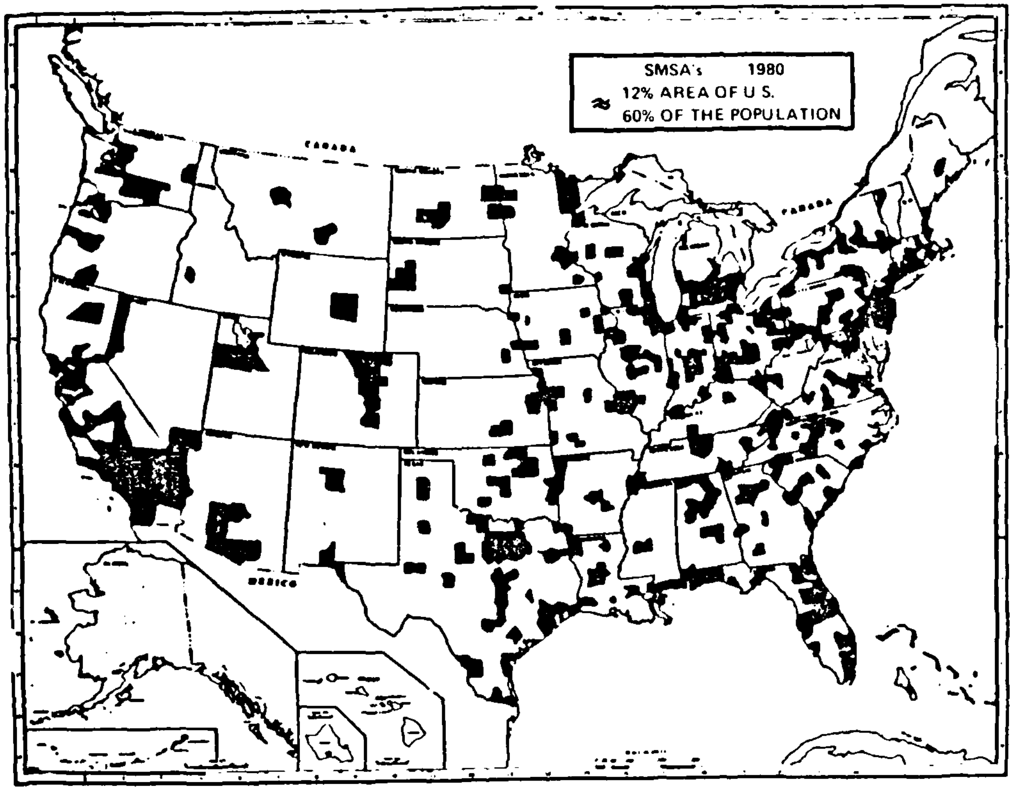
Additional economic benefits of a mobile satellite communications system, on the surface, appear mainly to accrue to the commercial sector

U.S. Census Report. The figure illustrates that approximately sixty percent of the population resides in the SMSA's but the SMSA's cover only twelve percent of the nation's area. According to the advocates of a mobile satellite system, if a terrestrial cellular communications system was installed only in the SMSA's, almost ninety percent of the nation and forty percent of the population would still not have access to mobile communications.[3] However, in the more densely populated rural areas, such as along the east coast, a terrestrial, rural cellular-type mobile system could be supportable. A real problem with coverage will exist, however, in the less populated western states.

A Land Mobile Satellite Service could assist in saving lives by drastically improving response time during life-threatening situations. A viable communications system, not dependent upon fixed telephone lines, would be invaluable in disaster assessment, for coordinating search and rescue efforts, and directing disaster relief operations.[5]

Technical Benefits

The implementation of a land mobile satellite system would spur the creativity of system designers. Current U.S. endeavors include development of frequency



STANDARD METROPOLITAN STATISTICAL AREAS (U.S.)

Figure 3-1. U.S. Standard Metropolitan Areas.
(Source: NASA, June 1984)

nation as a whole. These benefits can be categorized into:

1) Benefits from ubiquitous mobile communications.
2) Technical benefits.
3) Economic benefits.
4) International benefits.

Ubiquitous Mobile Communications

A Land Mobile Satellite Service would help achieve affordable nationwide mobile communications by augmenting urban terrestrial cellular communications systems.[1] At the present time, cellular communications systems are economically feasible only in urban areas where the population is sufficient to support the huge investment in equipment and towers that such a system requires. However, the supporters of a land mobile satellite system argue that cellular systems won't be feasible in vast areas of the U.S. due mainly to economic, geographic (terrain), demographic (rural), and environmental reasons.[2] Figure 3-1 is a map of the U.S. depicting the nation's Standard Metropolitan Statistical Areas (SMSA's) as defined by the 1980

CHAPTER III

CIVILIAN APPLICATIONS

Introduction

The concept of a Land Mobile Satellite Service (LMSS) is well within our nation's technical capabilities. Implementation of such a system could provide the nation with a truly ubiquitous mobile communications service. One of the major questions to be answered is, "Do we really need a land mobile satellite communications system, and if so, how will it benefit us?" This chapter discusses benefits derived if a mobile satellite service is implemented; it illustrates applications of a mobile satellite service that have been used or are envisioned for use; and concludes with a survey of past and proposed experiments using a mobile satellite communications system.

Benefits of a LMSS

The implementation of a land mobile satellite service would provide many benefits to our

[31]"Asks for Land Mobile Satellite System Okay," Electronic News, October 3, 1983.

[32]"Skylink," Industrial Communications, September 16, 1983, p. 4.

[33]Ben Kobb, "Skylink Plans to Bring Satellite-Aided Personal Radio Down to Earth," Personal Communications, January-February, 1984, p. 56.

[34]Roy E. Anderson, "Satellites Meet Rural Needs," March 1, 1984, p. 72.

[35]Gladys M. Anderson, "Mobile Satellite System Will Serve Remote Areas," Sea Technology, May, 1984, p. 19.

[36]Ibid.

[37]Ibid.

[38]Roy E. Anderson, "Satellites Meet Rural Needs," p. 72.

[39]Ibid.

[40]Gladys M. Anderson, "Mobile Satellite System Will Serve Remote Areas," p. 21.

[13]Letter of James M. Beggs, NASA, to Mark S. Fowler, FCC, November 24, 1982.

[14]NASA, Petition for Rulemaking, November 24, 1982, p. 1.

[15]Ibid., p. 5.

[16]Ibid.

[17]Ibid., p. 6.

[18]Ibid.

[19]Ibid.

[20]Ibid.

[21]Ibid., p. 7.

[22]Ibid.

[23]Ibid.

[24]Ibid.

[25]Skylink Corporation, "Application for a Developmental Land Mobile Satellite Service," September 12, 1983, p. 1.

[26]Ibid., p. 117.

[27]Ibid.

[28]Ibid., p. 40.

[29]Ibid., p. 3.

[30]Jay C. Lowndes, "Skylink Files to Provide Mobile Service," Aviation Week and Space Technology, October 3, 1983.

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[1]Roy E. Anderson, "Satellites Meet Rural Needs," Telephone Engineer and Management, March 1, 1984, p. 72.

[2]National Aeronautics and Space Administration (NASA), to Federal Communications Commission (FCC), Petition for Rulemaking - Mobile Satellite Service, November 24, 1982, p. 35.

[3]Ibid., p. 36.

[4]F. Naderi, "An Advanced Generation Land Mobile Satellite System and Its Critical Technologies," IEEE National Telesystems Conference, November 7-10, 1982, p. B1.1.1.

[5]Ibid., p. B1.1.2.

[6]Jerome Freibaum, "Land Mobile Satellite Service," NASA Briefing, June, 1984.

[7]Ibid.

[8]Roy E. Anderson, "Signaling Characteristics in Satellite-Aided Land Mobile Communications," IEEE National Telesystems Conference, November 7-10, 1982), p. E.5.7.1.

[9]P. M. Bourdreau, R. W. Breithaupt, and J. L. McNally, "The Canadian Mobile Satellite Program," IEEE National Telesystems Conference, November 8-10, 1982, p. B1.2.3.

[10]Ibid., p. B1.2.5.

[11]Anderson, "Signaling Characteristics in Satellite-Aided Land Mobile Communications," p. E.57.1.

[12]Ibid., p. E5.7.4.

specific frequencies woluld be allocated by the FCC. Communications between the air mobile terminal and the satellite are proposed for the L-band (approxi-1500 MHz - 1600 MHz).[38] Access to the public switched telephone network (PSTN) would be provided in the Ku-band (14 GHz/12GHz) by using "simple, low-cost gateway terminals located at . . . telephone switching centers for public radiotelephone systems."[39] Private mobile systems would also have a gateway terminal located perhaps at their dispatch headquarters. There would be a single network operations center (NOC) to "coordinate all of the communications through the satellites, perform some data exchange and surveillance functions, and provide billing services."[40]

This firm's proposal outlines similar needs and justification for the licensing of a mobile satellite system as discussed in the previous two proposals. The policy issues concerning a mobile satellite communications system that are now before the Federal Communications Commission are extremely important and they will be discussed in detail in Chapter IV.

The second commercial firm submitted a proposal to the FCC requesting the "authority to own and operate a land and aeronautical mobile satellite service."[34] The operation of this proposed system is theoretically similar to the previous proposals discussed.

This corporation plans to offer two kinds of service. The first is "stand-alone" service designed to take advantage of the propagation characteristics of satellite communications.[35] They propose to use narrowband modulation techniques in order to maximize the number of duplex voice channels within the band. They argue that use of these techniques can reduce the cost per channel to a proposed 15 cents per minute.[36]

The second type of service they plan to offer will be compatible with terrestrial cellular systems. The cellular terminal user will be able to use the satellite system when he is outside the range of the terrestrial system. However, the cost per minute will be more than for satellite use only because the bandwidth of the cellular system is wider.[37]

Communications between the mobile terminal and the satellite are in the UHF band (806 MHz - 896 MHz);

for each cell and then interconnects the mobile terminal with the public switched telephone network.[17]

Interactive Data and Surveillance (IDS)

Interactive data and surveillance (IDS) is a new communications service network "based on computer-oriented packet protocols for automatically transferring packets of information between mobile units. . ."[18] via satellite. The IDS system allows "bursty" but low throughput data exchanges between mobile terminals and fixed gateway base stations.[19] This system can be used to provide position surveillance or automatic vehicle monitoring. Individual vehicles would be addressed with short digitally coded signals that are transmitted over a voice channel. The signal would last only a fraction of a second, and is relayed through the satellite back to the earth station. In the surveillance mode, the vehicle that is addressed automatically (through a polling technique) sends the signal back through two satellites. The earth station then measures the times it took the signal to travel each path, determines the distances from the satellites to the vehicle, and then computes the vehicle position.[20]

The position of the mobile terminal is computed at the ground station and within one second after the vehicle is interrogated, the earth station computer can print out the vehicle position.[21]

Interactive data and surveillance is efficient, cost-effective and convenient if the amount of data exchanged is kept to a minimum. The fact that "tens of thousands of IDS mobile units can share a single voice channel,"[22] makes IDS an affordable, spectrum efficient replacement for some voice services.

Trucking Industry

The above use of the mobile satellite system would be of great value to long distance transportation industries such as the trucking industry. Mobile voice communications, coupled with IDS, can improve the efficiency of the trucking industry in a variety of ways, especially for the intercity trucking companies whose trucks traverse many rural areas of the nation with access to mobile communications. One nationwide trucking firm estimated that "the ability to initiate communications to its drivers in transit would increase efficiency on the order of 15-20 percent. . . ."[23] This would result in savings in fuel, manhours, and repairs.

Time is important in loading and unloading cargo operations. A mobile satellite system would enable the dispatcher to know where the truck is at all times and divert it if necessary to pick up or deliver additional cargo. The dispatcher could also advise the driver if complications arise such as industrial conflicts, problems at pick-up and delivery destinations, etc.[24]

A mobile communications system would also provide the trucking company with a way to monitor driver performance[25] to ensure that working time rules are complied with.

A mobile satellite communications system would be invaluable in notifying authorities and obtaining assistance in case a vehicle breaks down.[26] The driver would also be able to alert the dispatch center and police about traffic accidents, thefts, and risks of damage from hazardous or perishable cargo.[27]

Agricultural and Forestry Industries

The agricultural and forestry industries have needs for mobile radio telephones in the unusually remote or rural areas where their operations take place.[28] In the agricultural industry, purchasing

agents for food processors and commodity markets need immediate access to pricing information so they can deal effectively with farmers and ranchers. In fighting forest fires, the use of mobile satellite terminals could quickly summon needed equipment, chemicals and supplies to the appropriate location.[29]

Advanced Life Support

Mobile communications via satellite is extremely beneficial in providing advanced life support assistance in rural areas of the country. Advanced life support is now provided by some ambulance services. Using mobile satellite communication, a trained paramedic in an ambulace on the way to the hospital, can administer emergency medical procedures while under the direction of a doctor located back at the hospital. Mobile satellite communications allows the paramedic to take life-saving steps on the way to the hospital instead of waiting until the patient arrives at the hospital. The few extra minutes that this procedure provides can be the difference between the life or death of the patient.[30]

Natural Disasters and Emergencies

Natural disasters or emergencies illustrate the perfect use for mobile satellite communications. No one can predict when or where a disaster situation will occur. Because of this unpredictability, an emergency communications system must be capable of operating anywhere, at any time.[31] However, due to the nature of disasters, "survivable and mobile or portable communications are not available . . . during the critical early phase of a disaster."[32] For example, when Mt. St. Helens in the state of Washington erupted in 1980, terrestrial land line communications systems in the area were destroyed, or those not destroyed were saturated. A U.S. Air Force jeep with a mobile satellite terminal was flown to the base of the volcano. Communications were established from the disaster site, via NASA's ATS-3 satellite, to an earth station in New York State. Telephone interconnections were then made in New York. This link carried vital communications during the first few days after the volcano erupted and until other communications could be established. The persons responsible for search and recovery operations were able to call nearly any desired place or person for assistance.[33]

The telephone network is an extremely important resource during disasters and emergencies. However, disasters sometimes occur where there are no telephones; the system may have been destroyed in the affected area, or the telephone system may become saturated with calls in the region surrounding the disaster, thus making it unusable to the people who need it the most. A mobile terminal can quickly be deployed to a disaster site, and almost immediately provide telephone service through a network entry point that is outside of the saturated area.[34]

Oil and Gas Industry

One of the major functions of the oil and gas industry is exploration and extraction of resources. Coupled with exploration is drilling, testing, and other support activities that require communications. However, the majority of this type of work is accomplished in remote areas of the country or in the ocean on off-shore drilling rigs. Because these activities are done at remote sites, telephone service is normally not available. In addition, some of the work is of a truly mobile nature, that is, crews continually move from one site to another.[35]

Presently, the majority of communications are accomplished by radio.[36] A land mobile satellite communications service could prove invaluable to these industries.

Temporary Construction Sites

Mobile communications via satellite are perfectly suited for use at temporary construction sites for the same reasons. Service could be set up and used at the site, but when the project was finished, the service must be discontinued. If a mobile satellite communications terminal was used, temporary telephone lines would not need to be installed and the upon completion of the project, either abandoned or removed. Only the mobile terminal would leave the site, and it would now be available for use elsewhere.[37]

Mobile Maritime Communication

Ships at sea benefit greatly from a mobile satellite communications system. The International Maritime Satellite Organization (INMARSAT) began operations in 1982 and there has been a rapid growth in the number of users of its maritime communications satellite system since then. By April, 1983, this number of users had grown to over 1,600.[38]

Although the frequencies used by INMARSAT's satellite (1.6/1.5 GHz)[39] are different from the frequencies requested and discussed for the land mobile satellite system, the maritime services operated by INMARSAT are the only civil mobile telecommunications links working via satellite that are in regular use today.[40] This illustrates that using satellites for mobile communication is not only desirable, but it can be done. INMARSAT provides a range of services via satellite for ship-to-shore communications. These services include telephony, 50-baud telex duplex and shore-to-ship channels. Facsimile and voice-band data transmission at bit rates of up to 2400 bits per second are also available. In the ship-to-shore direction, an optional high-speed data service is possible.[41]

The ship's mobile terminal antenna is only around one meter in diameter; however, it is designed to high standards, with,

> precision antenna pointing mechanisms that track the satellite . . . and also with stabilization to keep the dish on target as the ship rolls and pitches in the roughest seas.[42]

Because of the costs for the precision satellite terminal, it is seldom economical for installation on a ship weighing less than 1,600 gross tons. The

typical cost of such a terminal installed is $55-60,000.[43]

In the area of safety and distress services, INMARSAT has proved invaluable. Improved facilities for distress and "safety of life at sea" communications are provided. This could be augmented by an automatic tracking system. Either the satellite could automatically poll the ship, or the ship could voluntarily transmit position reports.[44]

There are many other applications for mobile maritime satellite services, and INMARSAT is continuing to explore the possibilities.

There is a wide variety of civilian applications for mobile communications via satellite. I have only skimmed the surface. As the use of satellites for mobile communications increases, and costs decrease, more ways to take advantage of these satellite systems will be developed.

Mobile Satellite Experiments

A number of experiments and studies have been conducted over the past ten years to determine if a land mobile satellite system is technically possible and economically feasible; and if so, how could it be used and what would be the demand for such a system.

NASA has been the main proponent in this respect. They have conducted user experiments using the Application Technology Satellites (ATS) -1, 3, and 6. These experiments have illustrated the wide diversity of applications of and needs for a mobile satellite communications system.

Emergency Medical Services

The Southern Regional Medical Consortium, under a contract with NASA, performed an experimental evaluation of satellite communications for emergency medical services. The study evaluated the demand, cost, and benefits of satellite communications[45] for emergency notification, vehicle dispatch, and two-way voice and biomedical telemetry between paramedics and hospital physicians.[46] The study concluded that the demand for emergency medical services (EMS) communications in rural areas was a function of the management philosophy and level of development of the EMS operation. The cost effectiveness of the communications system is sensitive to demand. In the evaluation, the cost per channel hour approached $1,000 for population densities of 10 people per square mile and decreased to $300.00 when the population density increased to 40 people per square mile.

Medical benefits accrued primarily to cardiac patients, and it was determined that on a national basis, approximately 34,000 cardiac patients annually could benefit from the use of an integrated satellite/terrestrial land mobile service.[47]

Disaster Assessment and Relief

Disasters can occur over a large segment of the world. Natural disasters such as hurricanes, floods, tornados, and volcanic eruptions can cause widespread destruction to life and property.[48] In 1979, a tornado struck Wichita Falls, Texas, killing 60 people, injuring close to 1,000, destroyed property, power and telephone lines. This tornado effectively cut the area off from all outside aid.[49] Only one emergency telephone link was established by the next morning. Additional communications were established by using NASA's ATS-6 satellite and a jeep-mounted satellite transceiver. This experimental equipment provided communications between Wichita Falls and state and federal emergency response agencies.[50]

Emergency communications using the Canadian/NASA experimental Communications Technology Satellite (CTS) provided assistance in 1978 when a flash flood

at Johnstown, Pennsylvania, destroyed all existing commercial communications systems.[51] When sea waves swept over Majuro in the Marshall Islands, an ATS-1 satellite terminal was used to establish disaster relief communications. The link ran from Majuro to the Public Service Satellite Consortium in Denver, and then to the Federal Emergency Management Agency (FEMA) in San Francisco.[52]

Law Enforcement

Law enforcement agencies could value from a land mobile satellite service. Present law enforcement mobile communications systems include an extensive network of costly transmitter and repeater sites. These are necessary to provide the type of complete coverage law enforcement agencies require. There are no major constraints placed on county and state police radio systems. But the costs are paid for by "significant expenditures in repeater stations"[55] and their upkeep. These costs exclude the initial cost of the ground station itself.[54] The costs of maintaining the fixed ground installations could be replaced by the costs of using a satellite for a "repeater" station, and thus provide benefits to law enforcement agencies.

Mobile Satellite Experiment (MSAT-X)

A cooperative mobile satellite experiment by the United States and Canada has been proposed for the near future. The goal of the joint program is to "develop the component and systems technology needed to enable first generation mobile communication satellites."[55]

The joint experiment will be conducted with three main objectives in mind. They are to:

1) Determine the role satellites play in providing thin-route mobile communications.

2) Identify, develop and evaluate system technology, and equipment in order to help configure a commercially acceptable network; reduce cost per channel; and efficiently use the scarce radio spectrum.

3) Transfer the capability to industry/government. The proposed launch of the MSAT-X is scheduled for some time in late 1987.[56]

Summary

From the above discussion, the benefits of the applications of a land mobile satellite service become apparent. The technology is available, need for and uses of such a system have been

illustrated. The completion of the joint mobile satellite experiment will emphasize how important mobile communications will become in the last part of the twentieth century and beyond.

(ITU) in order to obtain support for their plans for a mobile satellite system.[19]

Domestic Issues

In addition to the international issues arising from the proposed allocation of spectrum for mobile satellite service, the FCC is facing a very important domestic issue. The spectrum that is proposed for mobile satellite use is presently reserved for terrestrial cellular radio service. Those opposed to allocating this reserve spectrum to a mobile satellite service say the cellular radio system in the major urban areas will be saturated by the year 2000[20] and the reserve spectrum will have to be used in order to expand the cellular system. The opposition also feel that a mobile satellite system will interfere with the present cellular system. The wireline and nonwireline terrestrial carriers that have been authorized to compete for cellular mobile telephone service maintain "there is no justification for allocating scarce spectrum to a 'highly speculative' technology."[21]

The supporters of the mobile satellite system argue that the FCC authorized the creation of the cellular system based on the technique of cell

customers. If such a system were available in the U.S., it is quite probable that the U.S. would become a major user and therefore should participate in the design of the system.[17]

On the other hand, a decision by the U.S. not to develop a mobile satellite system, could prevent Canada from implementing a mobile satellite system because the Canadian system would interfere with U.S. terrestrial systems such as cellular radio. But because Canada is committed to developing a mobile satellite system, any action by the U.S. to prevent a Canadian system could damage the international cooperation presently enjoyed between the two countries. This could make it difficult for the U.S. to field future space or terrestrial systems that aren't completely compatible with Canadian systems.[18]

With the above in mind, the National Aeronautics and Space Administration (NASA) filed a petition for rulemaking (RM-4247) on November 24, 1982, requesting the Federal Communications Commission (FCC) allocate radio spectrum in the 800 MHz region for mobile satellites. Two commercial companies followed with applications for developing a mobile satellite system. Canada has also submitted proposals to the U.S. and to the International Telecommunications Union

mobile satellite communications system. The Canadian Department of Communications has been analyzing the utility and cost-effectiveness of a mobile satellite (MSAT) communications service. If the findings of the study are accepted, Canada could start full scale development, with a projected launch of the first MSAT by early 1988.[14]

Canada has made a commitment to the development of a mobile satellite system. There are two reasons for such a commitment. The first is to provide service to the 40 percent of the Canadian population that is not served by terrestrial mobile services and the second is development of space technology to allow Canada to remain competitive in the world market.[15] Canada must reach an agreement with the United States on the mobile satellite issue because the footprint of a Canadian satellite would spill across the U.S. border. In addition, present satellite technology prevents Canada and the U.S. from implementing their own independent satellite systems if they use the same spectrum.[16]

The U.S., because of its close proximity to its neighbors, is faced with either jointly developing and offering mobile satellite service or allowing Canada to develop the service and offer it to U.S.

corporation but by requiring a consortium of companies to develop a mobile satellite system.[11]

International Issues

At the World Administrative Radio Conference, 1979 (WARC 1979), frequency allocations were adopted which for the first time could bring satellite communications directly into the hands of the general public. Several countries, among them Canada and the United States, submitted proposals to allocate the 806-890 mHz band to mobile satellite service. These proposals, submitted by footnote, were generally accepted by Region 2 countries (mainly North and South America). However, they were accepted with the provision that the frequencies allocated would be limited to national service only and aeronautical operations would be excluded.[12] The allocation in Region 2 is:

> ADD 3670B Additional Allocation: in Region 2 the band 806-890 MHz is also allocated to the mobile-satellite, except aeronautical mobile-satellite, service on a primary basis. The use of this service is intended for operation within national boundaries and subject to agreement obtained under the procedure set forth in Article N13A.[13]

The western hemisphere, since WARC 1979, has had international approval for allocating frequencies to mobile satellite service. Canada, because of its size and population distribution, wants to develop a

Social Benefits

Another issue the FCC must consider is the social benefits the nation as a whole would derive if a land mobile satellite service is licensed and radio spectrum allocated to it. Will the mobile satellite service benefit the entire nation or only a limited segment of the country? If the system would benefit only a small part of the country, would that part of the country be the nation's rural population or would the benefit be derived only by private commercial concerns?[10]

Promoting Competition

The FCC is also faced with another issue. If operating frequencies are allocated to a land mobile satellite service, who does the FCC license to develop the system? Because the capital investments are extremely large, should the FCC license only one corporation based on the application and proposed system submitted, therefore encouraging a type of monopoly power, or should the FCC license all applicants, regardless of their proposal or financial ability to develop the system? Another possible alternative open to the FCC is to require cooperation between companies by not licensing a single

company would not have sufficient assurance that the spectrum would continue to be available to justify the investment that is required.[7]

The FCC must also consider the type of technology proposed. One corporation submitted a conservative proposal, hoping that if it is successful and the market demand is there, it could petition the FCC to grant more spectrum later. The other firm is requesting the full 10 MHz of spectrum from the very beginning.[8] But the spectrum management function of the FCC and its decision to allocate spectrum to a mobile satellite service is not "simply a question of superior engineering . . . it also rests on analyzing opportunity costs."[9]

If the decision is made to allocate the spectrum to the mobile satellite service, the FCC must then decide how much spectrum should be allocated to mobile satellites, and what frequencies they should use. Understandably, allocation of radio spectrum is an extremely important decision and cannot be made thoughtlessly. The FCC's decision to allocate radio spectrum for a land mobile satellite service must also be based on other factors which are discussed below.

The frequencies desired by land mobile satellite system proponents are presently reserved for terrestrial cellular radio. The FCC must consider the impact allocating the reserve spectrum to a satellite system will have on the probable expansion of the fledgling cellular radio industry. Can the type of communications proposed by mobile satellite be offered by existing cellular systems? Robert S. Powers, the FCC's chief scientist reflects on the decisions facing the FCC:

> If there is not enough initial demand to justify a satellite system, the choice might be a terrestrial system even though it would cost 10 times more over the long run.[4]

But even if satellites are more efficient, the issue is where will the reserve spectrum be needed more--for rural services or for expanded urban services.[5]

The World Administrative Radio Conference (WARC) in 1979, allocated the 806-890 MHz band to mobile satellite service on a "shared primary" basis.[6] Proponents of a mobile satellite service feel if the FCC decides to allocate frequencies to the development of land mobile satellite service, the frequencies must be allocated on a "primary" basis. If the frequencies are allocated on anything other than a primary basis, a commercial

spectrum for a land mobile satellite service is a decision the FCC must make in the near future. Any decision the FCC makes is likely to have wide ranging effects on the future of communications in the United States.

Issues Facing the Federal Communications Commission

The National Aeronautic and Space Administration's petition for rulemaking was discussed in Chapter II. Two commercial corporations' applications for licensing of a mobile satellite service were outlined. There are several basic issues facing the FCC concerning allocation of spectrum for and licensing of a land mobile satellite service. Each issue must be carefully considered and the benefits and consequences impartially weighed before a decision can be made.

Allocation of Radio Spectrum

The main issue facing the FCC is allocation of the radio spectrum. Because the FCC is charged with managing the frequency spectrum efficiently, the FCC must first decide whether or not to allocate the spectrum to a land mobile satellite service. This decision will be based on the following factors.

> interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all people of the United States, a rapid, efficient Nation-wide, and world-wide, wire and radio communication service with adequate facilities at reasonable charges, for the purpose of national defense, for the purpose of promoting safety of life and property through the use of wire and radio communication.[1]

The two basic functions of the FCC, in order to carry out the responsibilities vested by the Congress, are

1) Regulation of Interstate Common Carriers,

2) Management of the Radio Spectrum.[2]

Under the function of regulating interstate common carriers, the FCC's responsibilities include issuing a "certificate of public convenience and necessity" required by new firms entering the communications industry and by existing common carriers wishing to expand their systems.[3] Under the second function, management of the radio spectrum, the FCC must review applications and license the use of one of the nation's most scarce national resources--the radio spectrum.

The above duties must be carried out responsibly in order to provide viable communications and protect the public from harm. These are no easy tasks. Technology changes so rapidly and these changes must be evaluated. The allocation of radio

CHAPTER IV

TELECOMMUNICATIONS POLICY ISSUES

Introduction

The above sections have illustrated the viability of a satellite-aided land mobile service and its value to various segments of the U.S. population. NASA has petitioned the Federal Communications Commission (FCC) to reallocate radio spectrum for use by a commercial land mobile satellite service. Two commercial companies have filed applications for licensure of a developmental land mobile satellite system. They have illustrated that a land mobile satellite service is technically possible, economically feasible, and a market demand exists for the services. However, there are additional issues that must be considered before a land mobile satellite service can become a reality.

The FCC's Mandate

The FCC is an independent regulatory agency created by the U.S. Congress under the Communications Act of 1934. By enacting this Act, Congress endowed the FCC with extremely broad powers to regulate

prepared by University of Southern Mississippi under NASA Contract NAS 13-95, December 1980, p. 2.

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[47] Southern Regional Medical Consortium, p. 168.

[48] Jerry Freibaum, "The Application of Mobile Satellite Services to Emergency Response Communications," IEEE ICC 1980, June 1980, p. 35.2.3.

[49] Ibid., p. 35.2.2.

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[32] Ibid.

[33] Roy E. Anderson, "Satellite Augmentation," p. 507.

[34] Ibid., p. 511.

[35] ECOsystems International, Inc., "Analysis of the Oil and Gas Industry Market for a Land Mobile Communications Satellite Service," January 18, 1982, p. 6.

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[38] Chris Bulloch, "Keep in Touch Wherever You Go," Interavia, April 1983, p. 351.

[39] Ibid.

[40] Paul Branch and Alex Da Silva Curiel, "INMARSAT and Mobile Satellite Communications," Telecommunications, March, 1984, p. 30.

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[42] Bulloch, p. 351.

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[45] Southern Regional Medical Consortium, "An Evaluation of the Experimental Application of Mobile Satellite Communications in Rural EMS Systems: Demand, Costs and Benefits," Report

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[19] Ibid.

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[22] Ibid., pp. 19-20.

[23] Roy E. Anderson, "Satellite Augmentation," p. 507.

[24] Tord Freygard, "Feasibility of International Transport Communications System," IEEE ICC 1982, p. 7H.4.3.

[25] ECOsystems International, Inc., "Analysis of the Trucking Industry Market for a Land Mobile Communications Satellite Service," January 11, 1982, p. 5.

[26] Ibid.

[27] Freygard, p. 7H.4.3.

[28] Roy E. Anderson, "Satellite Augmentation," p. 507.

[29] Ibid.

[30] Ibid.

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[15]Roy E. Anderson, "Satellite Augmentation of Cellular Type Mobile Radio Telephone Systems," ACTA-Aeronautica, 9, no. 8 (1982), 512.

division to provide increased capacity through frequency reuse. When the system reaches full operating capacity in its present configuration, the cells will be divided into smaller cells, according to the original operating concepts. However, from an economic point of view, it is obviously more costly to the cellular system operator to divide his system into smaller cells and build new transmitter sites and switching centers than it is to expand its operation into the reserve bands.[22]

Summary

As illustrated in the above discussion, the FCC's decision to or not to allocate radio spectrum for the development of a mobile satellite system will have far-reaching effects in both the national and international arena. The FCC is scheduled to consider the NPRMs and comments received for allocating spectrum for mobile satellite service in the near future.

Notes - Chapter IV

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CHAPTER V

DEFENSE APPLICATIONS

Air Force Manual 1-1, Functions and Basic Doctrine of the United States Air Force states that:

> We must assure the sovereignty and physical security of the United States. This includes maintaining an international environment that allows us the freedom to sustain the welfare of our people. This requires continuous vigilance. We must maintain a position of strength, the capability for timely deployment of our warfare systems, the ability to fight when necessary, and the potential to resolve conflicts on terms favorable to our interests.[1]

This statement forms the basis for the development of the mission of the nation's Armed Services. The national goal is peace and in order to achieve that goal the nation must deter conflict by maintaining a force that is capable and ready.

Air Force Manual 1-1 continues with the following statement:

> For the nation to have an effective military instrument, the Military Services must be an efficient team of land, naval and aerospace forces. Through readiness, proper employment, and effective targeting, these forces can be decisive in crisis and conflict.[2]

The ability to command and control the armed forces at all times is crucial to meeting any situations that might arise. Communication is the key to commanding and controlling our land, naval and aerospace forces. The ability to rapidly extend communications to almost anywhere in the world, or to restore damaged communications if required, is vital to fighting and winning war.[3] With this in mind, the Department of Defense has developed many communications systems to be able to perform its command and control function. The important role satellites play in defense communications has been recognized by defense managers, and efforts to exploit the advantages of satellites for communication is extensive.

This chapter discusses the type operations our defense forces must be prepared for, defense communications needs, and present terrestrial communications systems and associated problems and limitations. The advantages of using satellites for mobile communications are outlined and the chapter concludes with a brief discussion of present and future defense mobile satellite communications systems.

Concept of Operation

The ability to communicate during any and all types of military operations is vital to our national defense. Military operations include exercises, limited war, general war, counterinsurgency and crisis management. All these type operations require the ability to be flexible, mobile, and respond rapidly to whatever the threat may be. To achieve this end, the armed forces must have a secure means of communication that is immune or highly resistant to enemy countermeasure and attacks of various kinds.[4] Defense communications requirements cannot be satisfied, operationally or cost effectively, by only one type of transmission system. Each type of communications system, whether it is terrestrial or satellite, has cost and/or operational limitations which prevent it from satisfying all operational communications requirements.[5] A combination of systems must be developed, integrated into the armed forces inventory, and employed. A flexible, integrated communications system will meet defense force requirements.

Defense Communications Needs

In order for the armed forces to be effective in all types of military operations, flexible, survivable, secure communications systems are needed. The tactical forces need highly reliable communications systems, capable of communicating over extended ranges. These communications systems must also be flexible in their configuration so they can adjust to changing battlefield conditions.[6]

Communications systems must also be redundant. There must be alternate communications available if part of a system fails, is jammed or destroyed. Communications must be decentralized. The armed forces cannot afford to have central communications nodes. If a node is destroyed, all units tied into that node cannot communicate with each other or with higher command authorities.[7]

Communications systems should also be able to operate with a very low probability of detection or interception. If a communications system is not detected, chances are it will not be a target for destruction or jamming.[8]

As new communication systems are developed, old ones should be able to be modified and operate

with new systems as well as still being operationally compatible with existing systems.[9]

Current Terrestrial Communications Systems

Current terrestrial communications systems that are used by the tactical forces include, radio relay systems, line-of-sight (LOS) systems, wideband troposcatter systems, high frequency single sideband (HF/SSB) systems, cable, and microwave systems. These systems have many drawbacks that will be discussed as follows:

Terrestrial communications terminals, because they basically use line-of-sight technology, are limited by distance and geography. These terminals must usually be set up on the highest point in order to see the distant end. Because they are line-of-sight systems, an extensive number of relays must be used in order to maintain system connectivity. Then the system is vulnerable to failure if even only one relay site is destroyed.[10]

Extensive planning and surveying must be accomplished at each probable communications site long before the site is needed to ensure that the site selected to set up a relay or end terminal

will actually be able to provide the quality communications needed by the mobile forces.

Terrestrial communications reliability is adversely affected by propagation conditions. This limits the reliability of the system. The antennas must be properly aligned to critical specifications. Because communications systems are so important to units at all levels of command, there is very little room for error in siting the communications antenna.

They also create large visual and electromagnetic terminal signatures, making them highly vulnerable to enemy detection, jamming and possible destruction.[11]

It is clear from the brief discussion above that terrestrial communications systems present significant shortcomings in a tactical environment. The use of satellites to provide mobile communications for tactical forces can overcome many of these gaps in the armed forces communications systems.

Satellites for Mobile Defense Communications

Using satellites to provide mobile communications can significantly improve the flexibility, survivability and responsiveness of the armed forces

in many ways. The provide, fast, efficient communications between fixed, transportable and mobile air, sea or ground terminals which may be separated by great distances.[12] Satellite systems provide this capability because they permit near global coverage, provide communications service to isolated areas, offer multiple transmission frequencies, and can support contingency operations better than most conventional terrestrial communications systems.[13]

Siting criteria for mobile satellite terminals are not as stringent as terrestrial microwave or troposcatter communications systems. The mobile satellite terminal antenna must be pointed towards the satellite but it isn't affected by any mountainous terrain that might be between the users. In addition, because the satellite terminal does not have to be sited on the highest ground around, it is much more capable of surviving an attack. The terminal can be situated in a valley, just as long as the antenna is pointing towards the satellite. Satellite terminals are capable of providing communications to diverse and geographically separated combat forces, intelligence sources and high-level decision and command authorities.[14]

One crucial service mobile satellite communications provide is the ability to interconnect with other arms of the defense forces. Without satellite communications, it would be difficult, if not impossible for ground forces to communicate with distant air and naval forces.[15] A war can no longer be fought by only one segment of the armed forces. Coordination and cooperation by all branches of the service is necessary.

There are some limitations, however, in the use of satellites for mobile communications. As the potential capabilities of communications satellites become widely recognized, demand for its use has dramatically increased.[16] Frequency congestion, lack of bandwidth and adequate jamming resistance are major problems facing the users and designers of satellite mobile communications systems.[17] Satellites cannot be viewed as a panacea for all the defense communications ills that exist.

First, present defense mobile satellite systems operate in the UHF (225-400 MHz) and SHF (7-8 GHz) frequency bands which are "inadequate to support protected communications,"[18] i.e., secure voice and data, for all military users. Secure

communications require large amounts of bandwidth for signal encryption and to null out the effects of enemy jammers.

A second problem arises because the above frequency bands are already overcrowded. These bands are "congested because they are also used heavily in European nations for terrestrial radio-relay communications."[19] Coupled with this is the limited number of geosynchronous orbital slots available for defense satellites. Orbital positions are crowded, and the U.S. is not the only nation vying for these satellite slots.[20]

However, despite the drawbacks, system development and operation in this band have taken place because the technology is relatively cheap and available. This has great significance when one considers the large numbers of terminals required by the armed forces. In this respect, the ground terminal costs become the dominant economic factor because so many terminals must be manufactured to fill defense needs.[21]

A major problem exists in the dedication of communications satellite channels within the Department of Defense. Satellite communications have become so important to defense operations, but the availability

is still limited. Defense communications planners fear that present satellite communications systems could not adequately handle the great demand for communications once a war has begun.[22] However, the Department of Defense is working to improve the availability, reliability and survivability of satellite communications systems.

Defense Mobile Satellite Communications Systems

Currently the Department of Defense operates three satellite communications systems. These three systems, Fleet Satellite Communications (FLTSATCOM), Defense Satellite Communications System (DSCS) and Air Force Satellite Communications (AFSATCOM), are made up of ten active military-use only satellites in geosynchronous orbit, and transponders on commercial satellites that have been leased by the Department of Defense. A new satellite system, Milstar (military strategic and relay) is being designed "from start to finish" as a war-fighting system serving both tactical and strategic forces worldwide.[23] Figure 5-1 illustrates the three communities served by military satellite communications system and the Department of Defense trend to more sophisticated

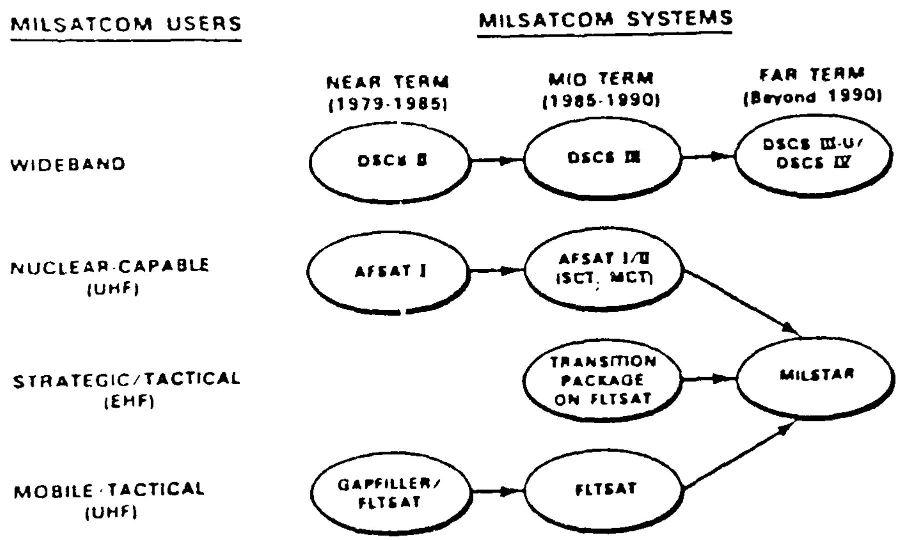

Figure 5-1. MILSATCOM Trends. (Source: Charles W. Niessen, "MILSATCOM Trends," IEEE International Conference on Communications, 1983, p. C1.5.4.

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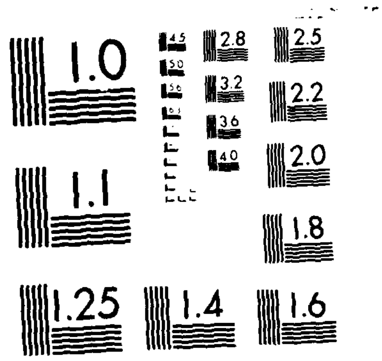

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satellite communications systems. Present FLEETSATCOM, DSCS and AFSATCOM designs, together with the proposed MILSTAR system, will be discussed below.

The type of satellite ground terminal used with the present communications satellite systems varies. There are approximately 160 fixed and transportable terminals placed throughout the world; there are mobile terminals installed on approximately 400 ships and 100 aircraft, and some 60 shelter or vehicle-mounted terminals used by the ground mobile forces. This terminal inventory is programmed to increase to over 2,500 terminals within the next few years. This total inventory will be dominated by mobile terminals.[24]

Satellite communications systems are continually evolving in order to provide additional capacity, and meet operational needs. Present systems use UHF and SHF frequencies, but with the development of MILSTAR, they are evolving into the EHF band. The present systems and some considerations are discussed below.

Defense Satellite Communications System

The Defense Satellite Communications System (DSCS) is an:

> integral component of the global DCS [Defense Communications System], designed to provide vital command, control, and communications (C^3) service to the U.S. and allied forces throughout the world by means of satellites.[25]

The DSCS system provides secure voice, high-capacity, and high-data rate, global communications through the use of SHF frequencies. The system supports critical communications requirements of the National Command Authority (NCA), the Worldwide Military Command and Control System (WWMCCS), the Ground Mobile Forces (GMF), the Defense Communications systems, the White House Communications Agency, and other U.S. agencies.[26] The present DSCS system is composed of four active geosynchronous satellites and two on-orbit spares. This system consists of a mixture of DSCS phase II and phase III satellites. The system provides almost global coverage with the exception of the extreme polar regions.[27]

Each of the Phase II satellites has 1300 two-way voice circuits with multiple access capacity through fixed terminals and transportable, ground-mobile, ship and airborne command post terminals.[28] The satellite has two dish-shaped antennas which are steerable by ground commands, and provide spot beams. Because these antennas can concentrate their coverage

into small beams, and direct these beams to cover desired portions of the earth, it is possible to use small, portable or mobile ground terminals. One of the important uses of the DSCS system is to support the Ground Mobile Forces of the Army, Air Force, and Marines. Two earth-coverage horn antennas are used, one for transmitting and one for receiving, and they provide wide and fairly uniform coverage of the part of the earth that is visible to the satellite.[29]

The DSCS Phase III satellite improves the capabilities of the Phase II version. It has improved capacity to handle small and large terminals because the satellite is capable of switching between earth coverage antennas and multiple-beam antennas (MBA).[30] There is also a steerable transmit dish antenna that provides a spot beam with higher radiated power designed for mobile terminals with small receivers.[31] Anti-jam capacity is provided through the use of multiple beam antennas to allow nulling of jammers. The satellite is also hardened to prevent damage from nuclear effects.[32]

The area of primary interest here is the use of DSCS to support the Ground Mobile Forces (GMF). Although the majority of the terminals used

by the Ground Mobile Forces are transportable, because of their size, they are not truly mobile. The satellite terminals that support the ground mobile forces are designed to be set up and torn down quickly. Although they are smaller than the powerful fixed earth stations, and they are capable of changing their operating location, they operate on fixed satellite ground terminal principles. The larger systems are not truly "mobile" but they allow the Ground Mobile Forces to pack up and move to new locations in a minimum amount of time, therefore reducing vulnerability to detection and attack.

However, the services have developed a truly mobile ground terminal called the Single Channel UHF Manpack transceiver. This system is a self-contained, battery-operated, single channel, half duplex UHF satellite communication transceiver that weighs 25 pounds. It will be used by long-range patrols, forward operating units, and special forces to link soldiers in battle.[33]

Fleet Satellite Communications FltSatCom)

The Fleet Satellite Communications system provides communications for strategic and tactical users, including strategic bombers, Navy land, sea,

air and submarine forces, and the joint services Rapid Deployment Forces (RDF).[34] Four satellites orbiting as depicted in Figure 5-2 provide near global coverage.

The FltSatCom satellite system has many missions. The satellite system operates using UHF frequency bands. This allows the use of small, simple antennas and relatively low cost terminals aboard ships and other mobile stations.[35] The satellite provides one fleet-broadcast 25 kHz channel and SHF beacon. Data and messages are provided in a broadcast mode only from shore to sea and air stations.[36] There are nine fleet relays, each a 25 kHz channel, that provide the Navy with worldwide tactical voice capability. Twelve narrowband, five kHz channels are provided for and used by the Air Force. This mission, piggybacked onto FltSatCom, provided UHF teletype communications to bombers of the Strategic Air Command. Finally, one 500 kHz channel provides the DOD with wideband communications.[37]

The DOD is planning to procure additional FltSatCom satellites in order to extend the life of service provided. An EHF transition package will be added on some of these additional satellites.[38] This EHF transition package will be a precursor to MILSTAR.

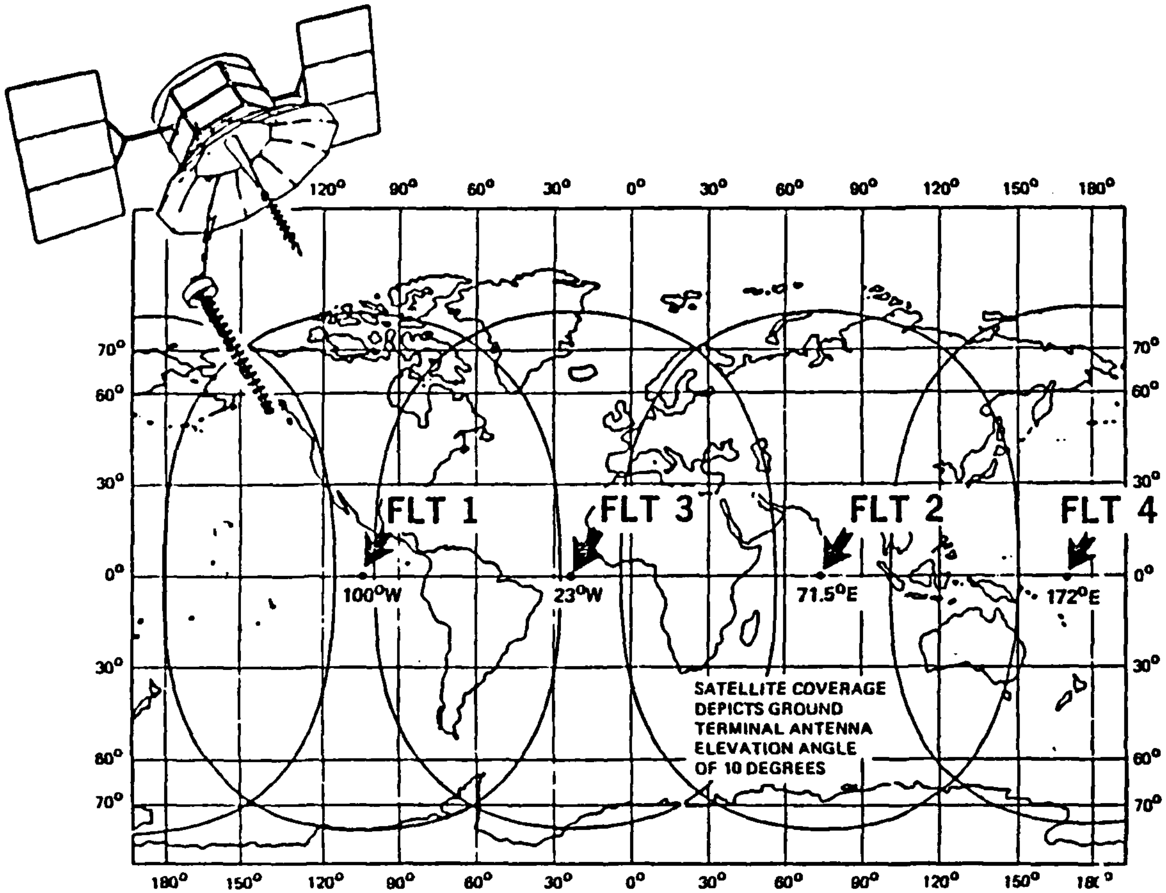

Figure 5-2. FLTSATCOM Coverage. (Source: "H. S. Braham, "FLTSATCOM-Current and Future," IEEE International Conference on Communications, 1982, p. 6H.3.1.

Air Force Satellite Communications System

The Air Force satellite communications system (AFSATCOM), as mentioned above, is presently piggy-backed onto the FLTSATCOM satellite. The goal of AFSATCOM is to provide a communication, command and control system for the "control of our strategic nuclear forces, that is capable of withstanding physical and jamming attacks."[39] AFSATCOM uses low power UHF terminals on strategic aircraft to provide low speed teletype messages for force execution, reporting and redirection. This system is also used in missile launch centers and weapon storage sites.[40]

MILSTAR

The Department of Defense is developing an advanced military communications satellite that will have nuclear-hardened electronics, be jam-resistant, and be capable of signal transfer from one satellite to another without going through a ground station. These capabilities should wipe out many of the shortfalls that exist in present satellite communications. Deputy Under Secretary of Defense for C^3I, Donald Latham, said,

> Today's communications system exhibit significant shortcomings in survivability and endurance, as well as capacity, connectivity and signal covertness . . . the current satellite systems . . . have zero to minimal anti-jam capability, almost nonexistent interoperability, and are unprotected from electromagnetic pulses (EMP) or nuclear radiation. Only the latest version of the DSCS satellite . . . has EMP hardening and AJ nulling capabilities. Still, the overall milsatcom architecture as it exists today, . . . could easily be jammed, have its ground nodes destroyed, leaving field commanders with lifeless terminals and little communications capability.[41]

The MILSTAR system will improve global coverage capabilities. It will consist of seven satellites with one orbital spare parked in three-axes stabilized orbits. Four will be at geosynchronous orbits above the equator and three will be in highly elliptical polar orbits. These polar orbits will provide communications coverage for the strategic aircraft, ships and submarines that operate at latitudes above 70 degrees.[42] The satellites will have cross-link capabilities; that is, they will be able to transfer data from one satellite to another without beaming down to a vulnerable ground station.[43]

The first MILSTAR satellite could be launched as early as late 1987. The remarkable anti-jam capability of the satellite system will be possible by using frequencies in the EHF band. MILSTAR's uplink will be at 44 GHz, and the downlink will be

at 20 GHz.[44] The anti-jam technique is possible because the "greater bandwidth available at EHF permits the use of spread spectrum/frequency hopping techniques across a 2 GHz range."[45] Present anti-jam systems such as AFSATCOM, is limited to a very narrow five kHz hopping range.

MILSTAR can provide a much needed advantage in command, control, communications, and intelligence (C^3I) over what presently exists today. However, because this development will be in the EHF bands, design allowances must be made so MILSTAR is compatible and interoperable with ground terminals in the field today. The spacecraft technology will be expensive, but even more critical will be the costs of developing and fielding the associated ground terminals. It is estimated that "as many as 4,000 terminals"[46] will be needed. Will the nation be committed to the kind of defense spending this system will require?

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[43] Ibid.

[44] Ibid.

[45] Ibid.

[46] Ibid., p. 46.

CHAPTER VI

CONCLUSIONS

This analysis examined the feasibility of using satellites for mobile communications. Operational concepts and system descriptions were provided for both civilian and defense applications of mobile satellite communications.

For the civilian sector, whether or not satellites will be developed and used in mobile communications systems, is an issue that is being discussed right now. The Federal Communications Commission (FCC) has the responsibility and power to allocate spectrum for and grant a license to a land mobile satellite service. The decision the FCC finally makes will be based on a wide variety of issues examined in Chapter IV.

For the defense sector, satellites will continue to be developed and used to provide mobile communications for all sectors of the armed forces. There are other problems the defense forces must consider in their system designs, but they are so

because of the nature of the responsibilities--
National Defense.

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